

BNL 200 MeV Linac Availability and Reliability

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RHIC Retreat 2006

OUTLINE

- Introduction
- Linac Beam Requirements
- 2006 downtime data and analysis
- Future Improvements
- Conclusion



PHOBOS

10:00 o'clock

12:00 o'clock

BRAHMS & PP2PP (\vec{p})

2:00 o'clock

RHIC

4:00 o'clock

PHENIX (\vec{p})

8:00 o'clock

STAR (\vec{p})

6:00 o'clock

NASA - BAF

μ g-2

HEP/NP (p)

LINAC

BOOSTER

AGS

TANDEMS

LINAC Beam Parameters

■ Final Energy	200 MeV
■ Peak Current	30-40 mA/ ~ .5 mA polarized
■ Trans. Emittance(n,rms)	2 pi mm mrad
■ Energy Spread	± 0.1 MeV (0.1 %, 95%)
■ Energy Jitter	± 0.1 MeV
■ Chopping	Slow + fast

Linac Requirements

■ RHIC/Booster

To booster one pulse every super cycle (Pulse width 226 μ s)

To HEBT one pulse every super cycle (Pulse width 302 μ s)

Super Cycle 3.800244 s

peak current $\sim 200 \mu$ A

■ BLIP

6.67 Hz

pulse width $\sim 400 \mu$ s

Beam current ~ 38 mA

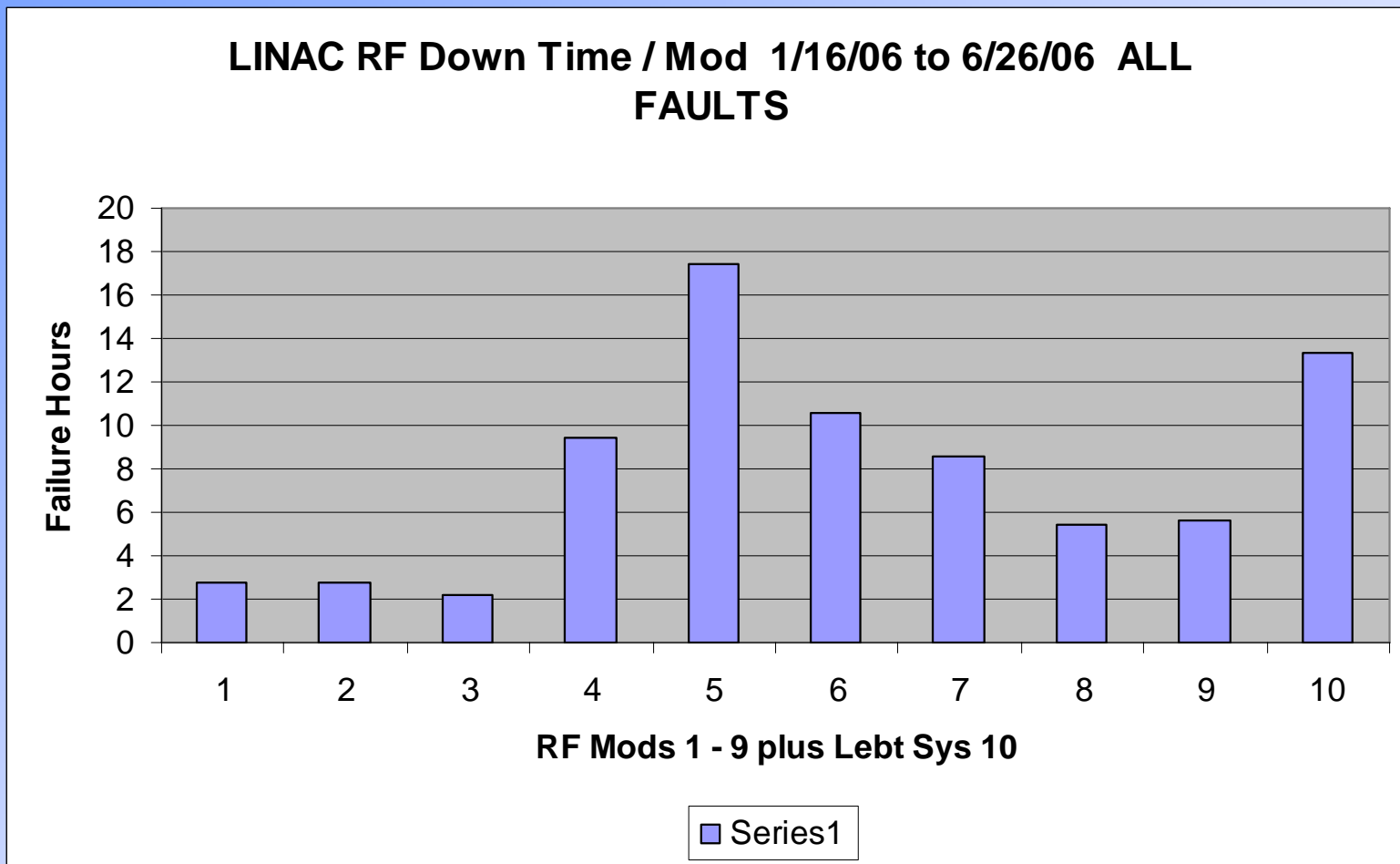
■ Other

NSRL, REF

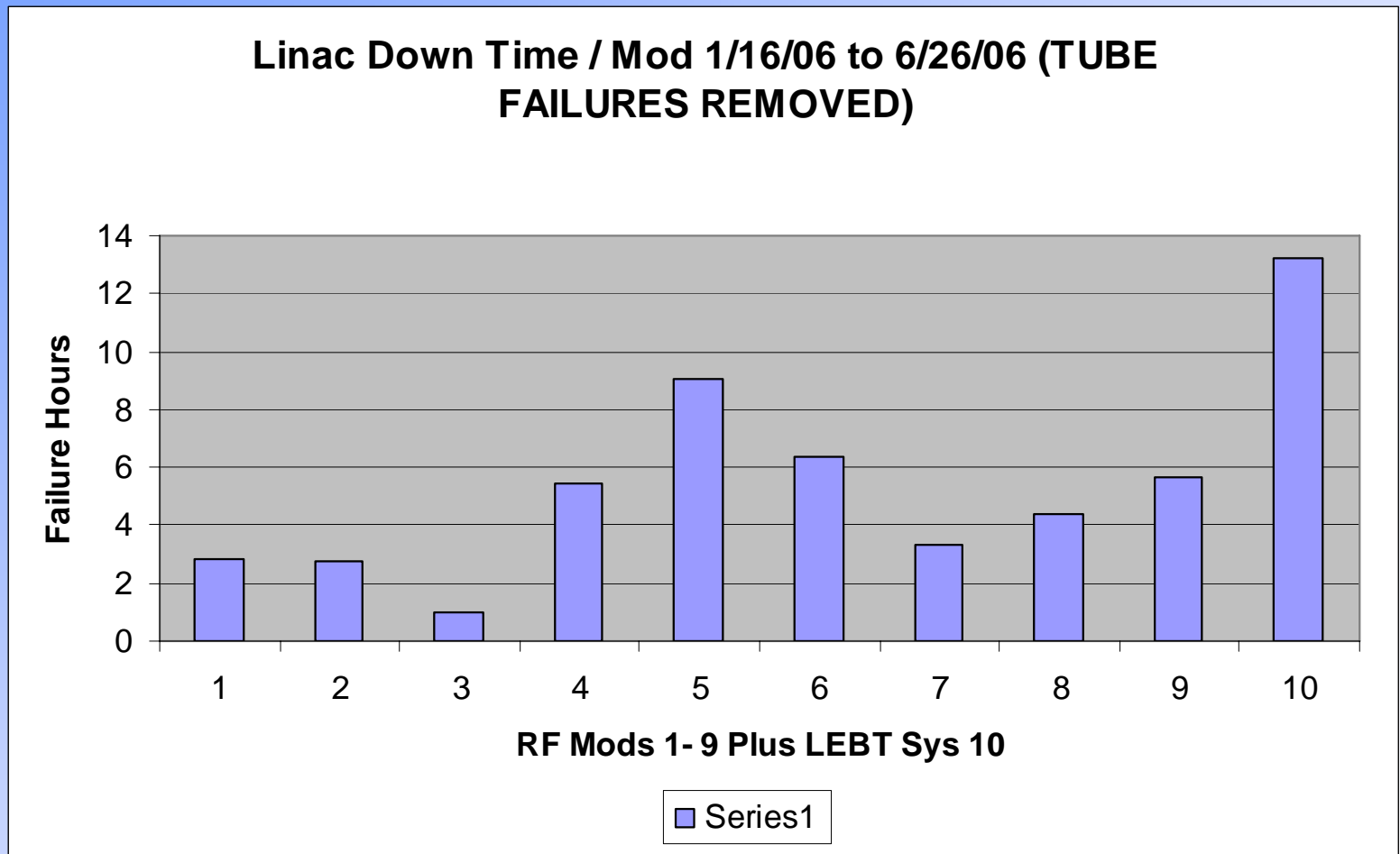
2006 down time and analysis

■ Our average availability	~ 95%
■ 2006 availability	95%
■ Total down time in 2006	134 Hrs
■ LNRf down time	78.1 Hrs (58.3%)
■ Tube failure	35.6 Hrs (27%)
■ Random Interruption (<15 min)	7.1 Hrs (5.3%)

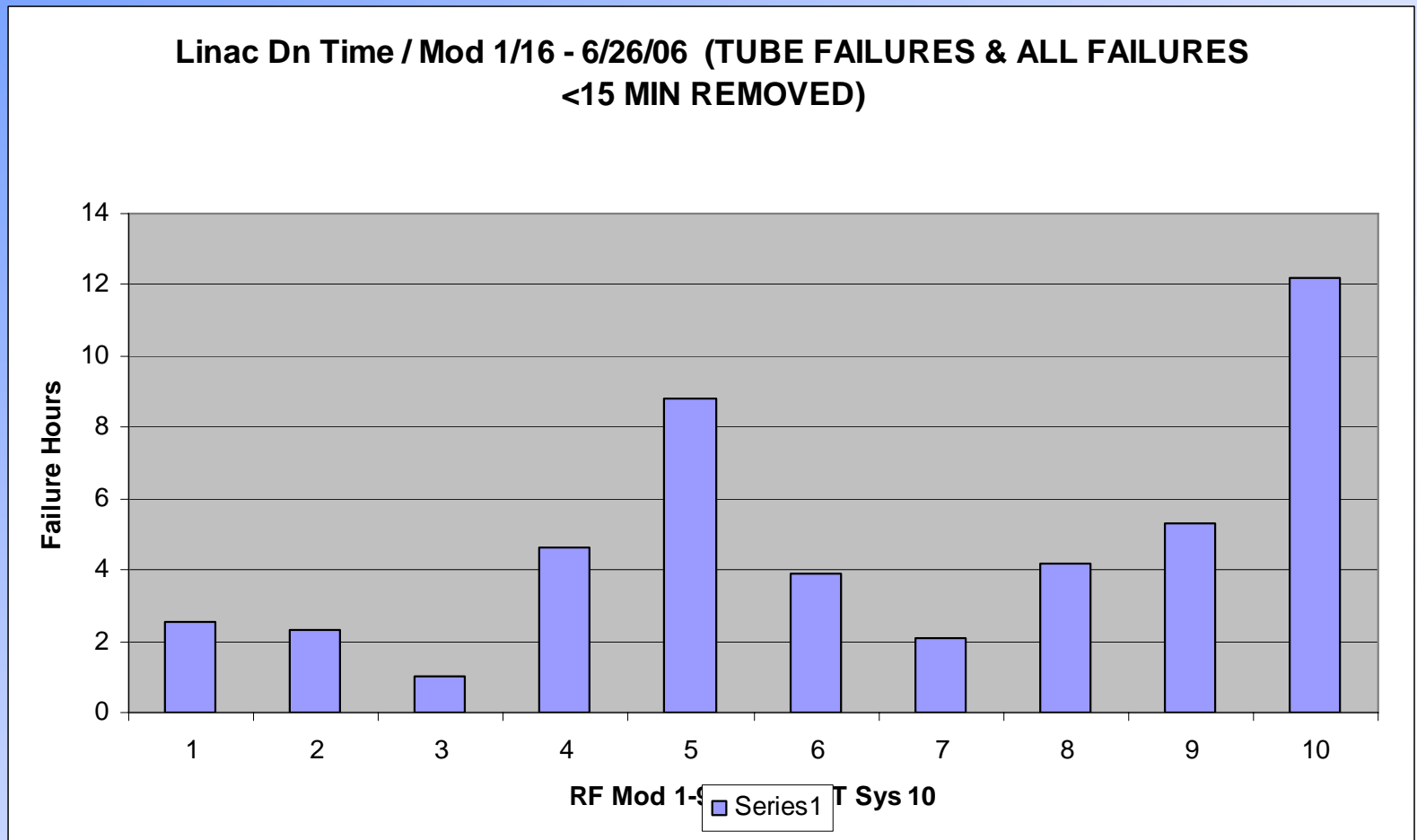
LINAC RF down time



LINAC down time (tube failure removed)



LINAC down time (tube failure and <15 min interruption removed)



Other equipment failure

- Modulator SCR Controller Bucket, 2 failures, new low level power supplies have been ordered for replacement, as well as high power version of an internal line driver which has a high failure rate.
- RF Cabinet Blower motors and mountings, 2 failures, new shock mounts have been ordered for all motor mountings.
- 4CW and 7651 anode PS output resistors, 2 failures; an internal small cooling fan will be added to the PS chassis. Prototypes have been completed.
- Modulator Telemeter Chassis, 2 Failures, a new design is in process replacing the old bi-polar transistors with a new higher voltage FET. We hope to have it ready for next year's run.

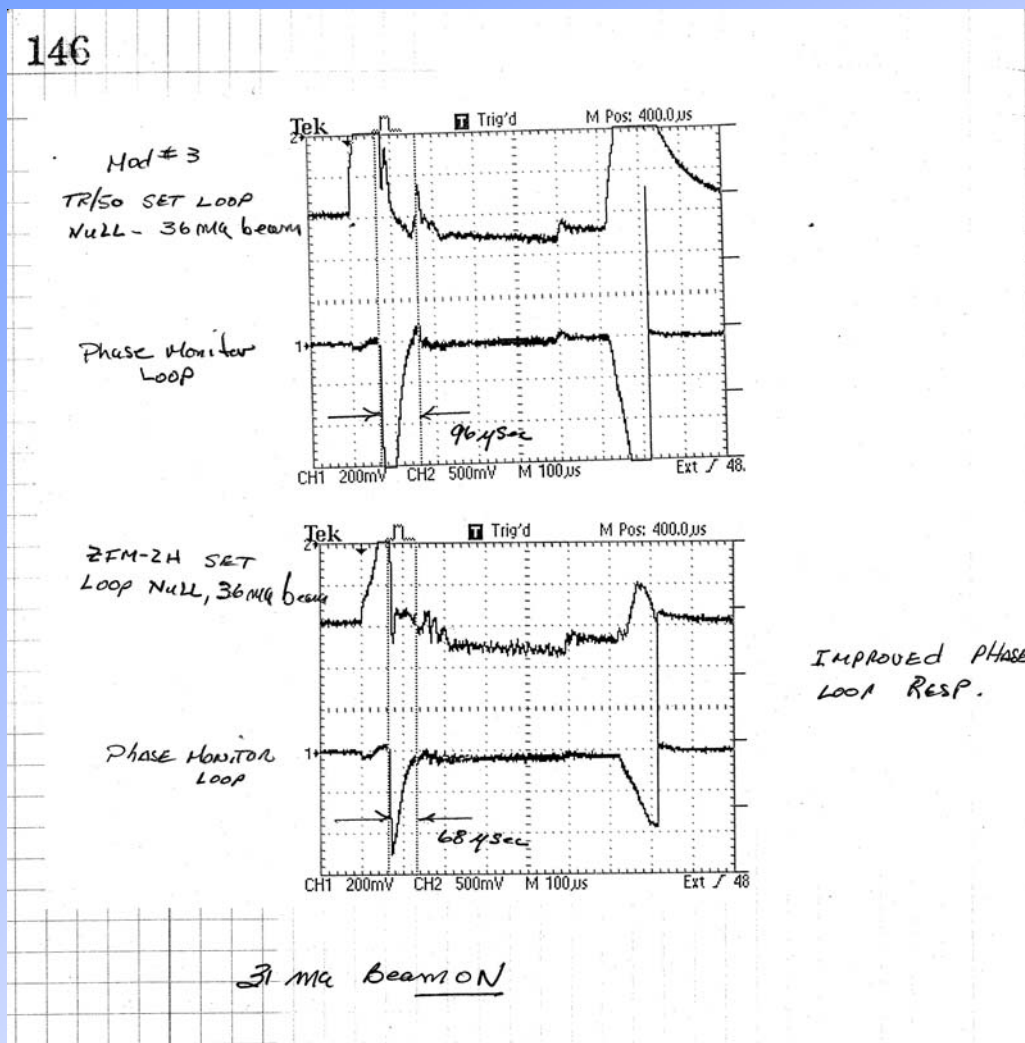
OPPIS

- Continually improving reliability (learning curve)
 - This is longest physics run for OPPIS
 - ECR maintenance 1 week->2-3 week
 - Solid state laser
 - Spare parts (new solid state extractor modulator)
- Longest (6.5 Hrs) down time due to water cooling system failure on the Extractor deck of the sodium cell
 - modified to exclude water in vacuum system

Linac availability improvements

- Big improvement due to PLC in rf system
 - Automated reset
 - Still 4 modulator and 8 drivers remaining
- Solid State mixture improved transient time reduce beam loss
 - Temperature on the carbon block in blip line reduce by 20%

Improved transient time



BLIP

- Temperature monitoring system on the carbon blocks at end of the blip line
 - Result in better tune reducing beam loss in the blip line

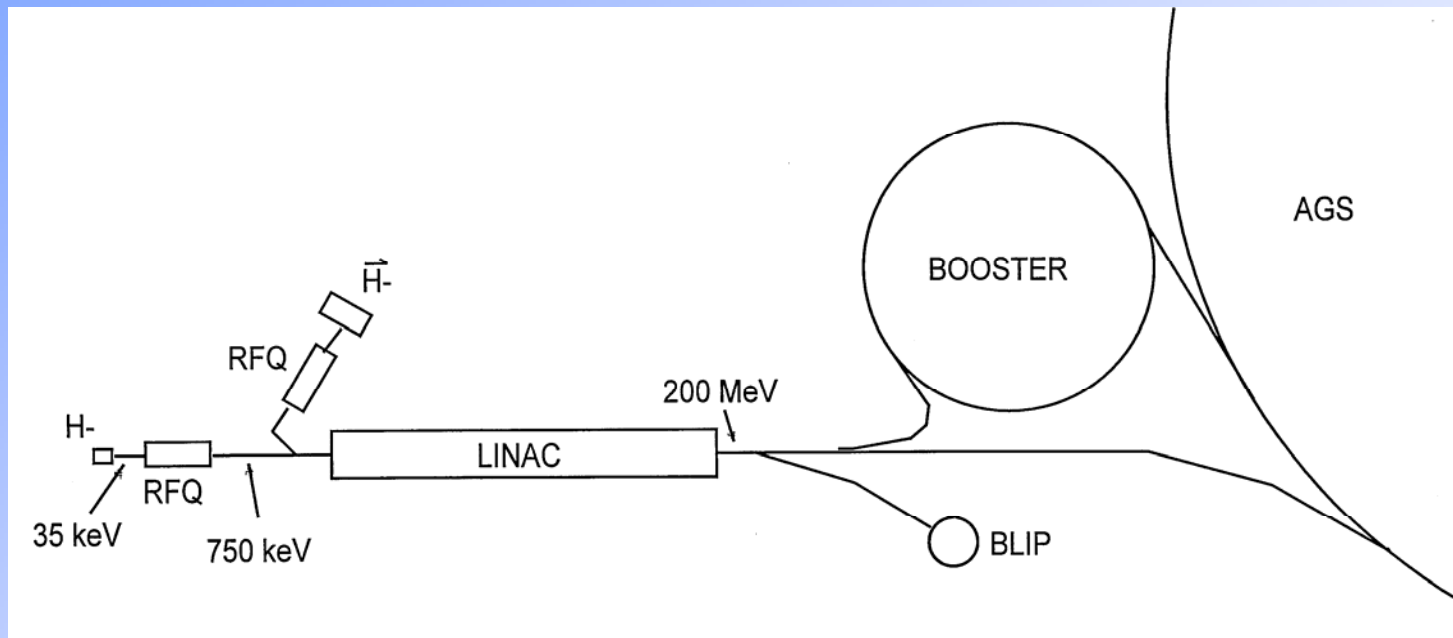
Future plan

- Complete modification in linac RF control PLC
 - 4 modulators
 - 8 Driver
- PLC control for H- source/LEBT
- Change buncher rf system to solid state

Conclusions

- Continuously improving reliability of linac
- Linac serves many customers
- Biggest demand on the system from BLIP
- Beam study time must help to improve linac performance

Linac Layout



Linac History

- Construction started -April, 1967
- First Beam - November, 1970
- Total Facility Cost 22.5 M\$

Year	Rep-Rate μ s	Beam Width mm	Current mA	Avg. Current μ A	1970	10	Hz
200	55	100	200	1972	10	100	
	60	44		1973-75	10	100	
	60	60		1976-			Switch to 5
Hz Operation				1979	5		220
50-70		55-77		1982			Switch to H-
acceleration				1984	5		200
25		25		1984			Add Polarized
H- Operation				1986	5		470
25-30		59-71		1989			Switch To
RFW Pre-Injector				1990	5		500
25		63		1996	7.5	330(500)	
38		95(155)		2000			Add OPPIS
for polarized Proton							

Linac

- Basically the same as FNAL's, built in 1970
- Performance - transmission, emittance, beam loss, radiation levels/activation
 - Stable from year-to-year with respect to operating values
 - No careful delta-t, etc. - could be better
 - Probably misalignments
- Vacuum for linac - Ion pumps/cryos

Linac Current & Emittance

Location	Simulation	Measurement
	Peak Current (mA)	
L3	62.9	62.9
L4	62.2	57.8
L5	54.6	53.2
T1	37.1	37.7
T9	36.4	35.9
	Emittance (rms,nor) pi mm mr	
RFQ	0.375	
Buncher	0.473	0.57
200 MeV	1.85	1.92
H SEM	+/-0.29 MeV	+/-8e-4 (del p/P)
Brookhaven Science Associates	+/-0.5 MeV	+/- 1.4e-3 (del p/PP)

BNL Linac

- 200 MeV
- 9 Accelerating Cavities
- 475 Meter Long
- 286 Cells (295 Quads)
 - 6 -84 cm/cell
 - 1.3 -40 cm/gap
- Average Field 2.5 MV/m , 5-10 MV/m in gaps
 - Tank1 56 cells, 10 MeV, 180 keV/gap
 - Tank9 19 cells, 20 MeV, 1MeV/gap

Linac Parameters

TABLE II.1.b.1

Summary drift tube table

200 MEV linac final drift tube table

A.B.

$$\phi_c = -32^\circ$$

Proton energy (MEV)

Proton velocity, β

Energy gain (MEV)

Cavity length (m)

Cavity diameter (cm)

Drift tube diameter (cm)

Bore hole diameter (cm)

D.T. corner radius (cm)

Bore hole corner radius (cm)

Cell length (cm)

Gap length (cm)

g/L

Axial transit time factor

Shunt impedance ($M\Omega/m$)

Drift space following cavity (m)

Accumulated length (m)

Number of unit cells

Number of full drift tubes

Average axial field E_0 (MV/m)

Average gap field E_g (MV/m)

Peak surface field E_{max} (MV/m)

Cavity excitation power (MW)

Total power/cavity for 100 mA (MW)

Total power/cavity for 200 mA (MW)

Factor x_i (Stem losses, etc.)

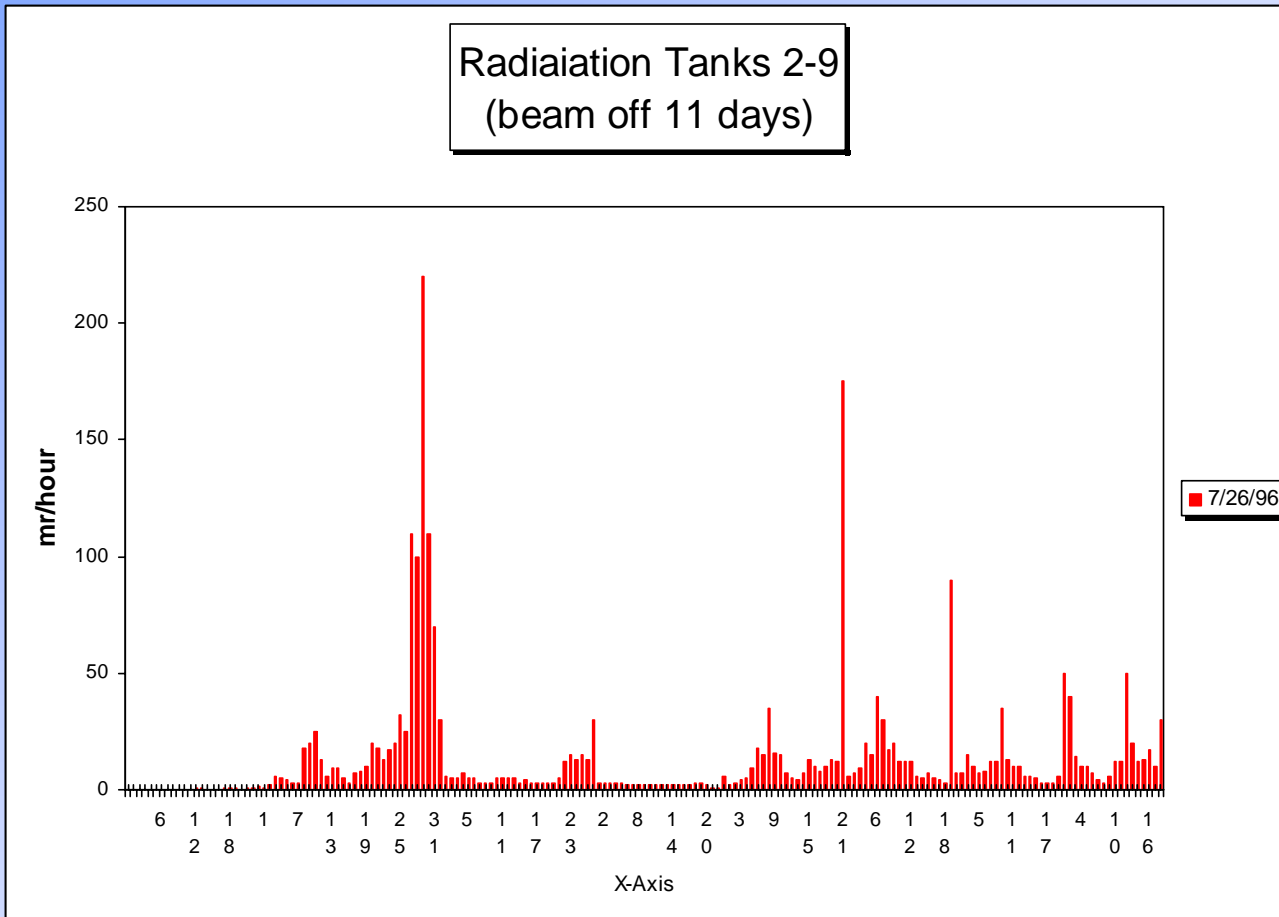
Cavity numbers											Total/ Final
In	Out	In	Out	In	Out	In	Out	In	Out	In	
0.75	10.42	37.54	66.18	92.55	116.54	138.98	160.53	181.01	200.30	200.30	
0.04	0.148	0.275	0.357	0.414	0.457	0.491	0.520	0.545	0.566	0.5665	
9.67	27.12	28.64	26.37	23.99	22.44	21.55	20.48	19.29	19.55	19.55	
7.44	19.02	16.53	16.68	15.58	15.54	15.83	15.88	15.73	15.73	15.73	
94	90	88	88	84	84	84	84	84	84	84	
18	16	16	16	16	16	16	16	16	16	16	
2.0	2.5	3.0	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	
2.0	4.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	
0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
6.04	21.8	22.2	40.8	41.1	53.0	53.3	61.5	61.8	67.9	68.2	73.1
1.3	6.7	4.4	12.7	12.2	19.3	19.5	25.1	22.6	26.9	27.1	30.8
0.21	0.31	0.20	0.31	0.30	0.36	0.37	0.41	0.37	0.40	0.40	0.42
0.64	0.81	0.86	0.81	0.82	0.75	0.75	0.69	0.73	0.69	0.68	0.65
27.0	47.97	53.5	44.8	44.6	35.2	35.0	28.5	29.6	25.0	24.8	21.7
0.22	0.6	0.75	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
7.66	27.28	44.56	62.24	78.82	95.36	112.19	129.07	144.80	159.7	174.6	189.5
56	60	35	29	24	21	20	19	18	17	16	15
55	59	34	28	23	21	20	19	18	17	16	15
1.60-2.31	2.0	2.60	2.60	2.56	2.56	2.56	2.56	2.56	2.56	2.56	2.56
7.62	7.45	10.0	6.45	8.7	7.2	7.03	6.3	6.9	6.4	6.1	5.8
8.9	10.2	12.6	9.7	13.1	12.9	12.9	13.2	14.0	14.1	14.1	14.2
0.51	1.40	2.36	2.57	2.75	2.91	3.13	3.19	3.24	3.24	3.24	3.24
1.48	4.12	5.22	5.21	5.15	5.16	5.28	5.24	5.17	5.17	5.17	5.17
2.45	6.84	8.08	7.85	7.55	7.41	7.43	7.29	7.10	7.10	7.10	7.10
1.30	1.30	1.35	1.40	1.45	1.50	1.55	1.55	1.55	1.55	1.55	1.55

* Bore hole diameter changes in cell # 18 (at start of full D.T. # 18).

$$\beta g = L/\lambda$$

$\cdot 0406$
 $\cdot 1491$
 $\cdot 2740$
 $\cdot 2760$
 $\cdot 3559$
 $\cdot 4130$
 $\cdot 4150$
 $\cdot 4560$
 $\cdot 4580$
 $\cdot 4909$
 $\cdot 4922$
 $\cdot 5198$
 $\cdot 5212$
 $\cdot 5447$
 $\cdot 5460$
 $\cdot 5662$

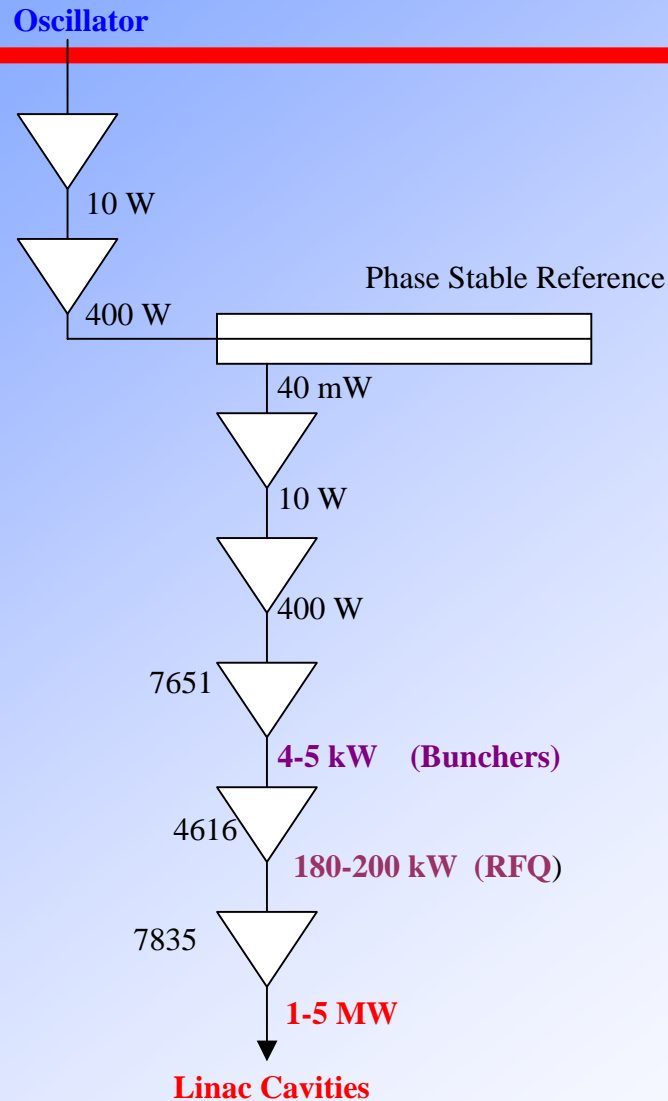
Radiation Along Linac



Linac RF System

- Schematic
- Photos
- Comments on new transmission line
- Tube lifetime, costs, etc.
 - 12000 hrs, \$20,000
 - 3 Tubes /years

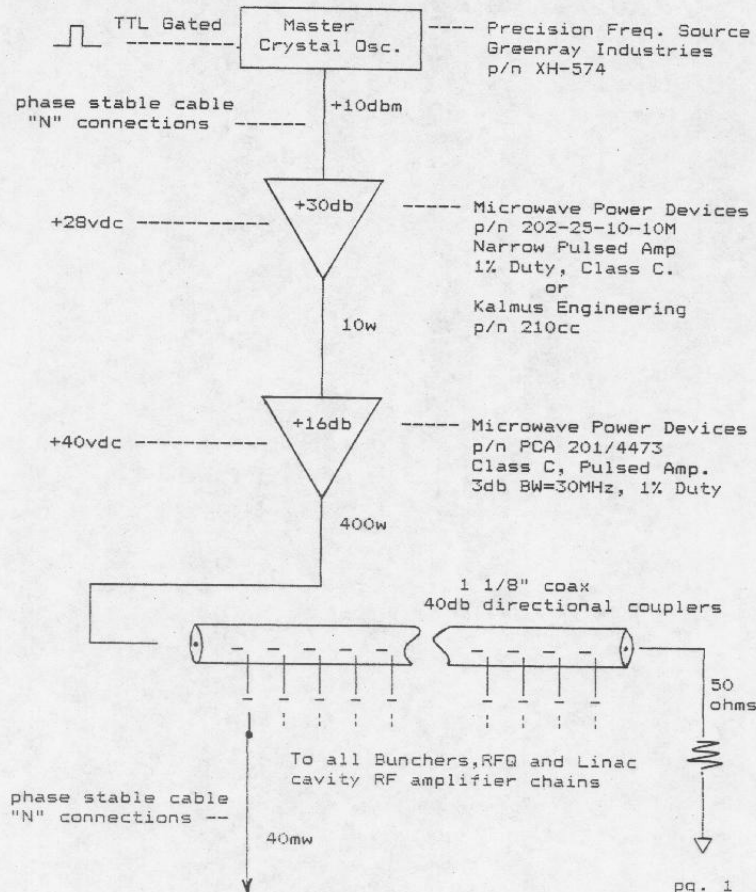
RF Systems



RF Systems (1)

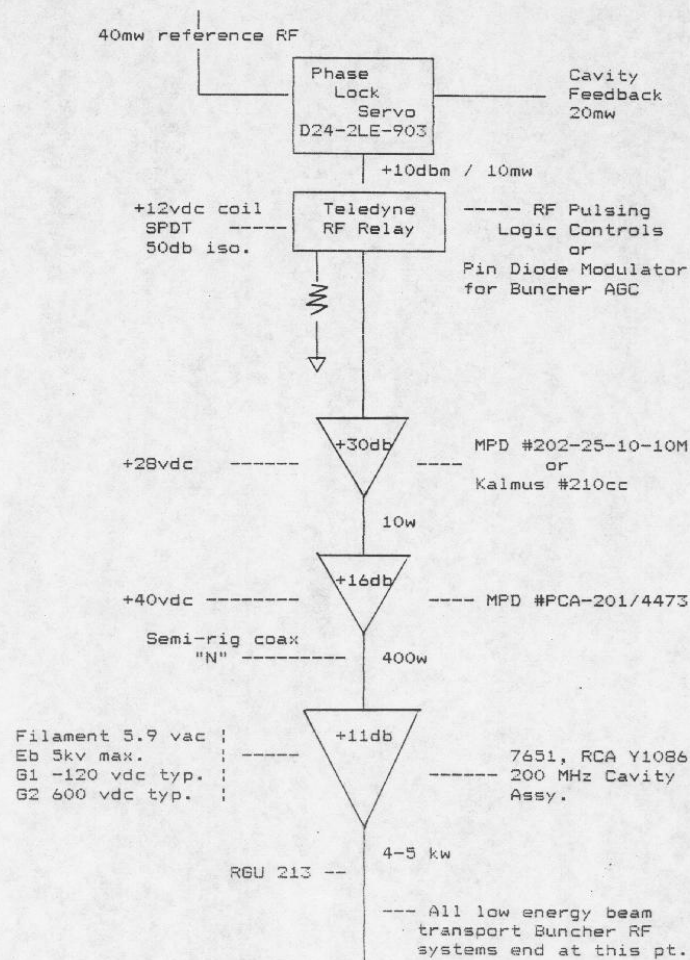
BROOKHAVEN NATIONAL LABORATORY 201.25 MHz RF AMPLIFIER CHAIN

Reference RF, Low Level RF, "LLRF:"



pg. 1

RF Systems (2)

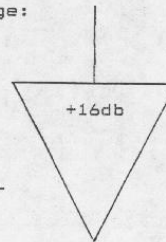


pg.2

RF Systems (3)

RFQ Final / 7835 Driver Stage:

Filament .95 vac @ 480A
Eb 17kvdc @ 25A typ.
(crowbar protected at >40A)
G1 -250vdc
G2 1.2kv pulsed or -----
DC Screen .8-1.5kvdc



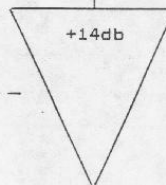
4616, RCA Y-1068
-- 200MHz Cavity
Assemblies.

3 1/8"
coax -----

180 - 220kw

Final, 7835 Power Amplifier:

Filament 4.7vdc @ 6800A
Eb 18 - 35kv pulsed
Ib 150 - 320 amps
(crowbar protected @ 400A) --
G1 -60 to -200v pulsed
@ 500 grid current
(grounder grid, 1/3 ohm)



--- Continental
Electronics 200MHz
7835 Power Amp Assy

12" Coax -----

--- 1 - 5 Megawatts

To Linac Cavity

RF Transfer-Line

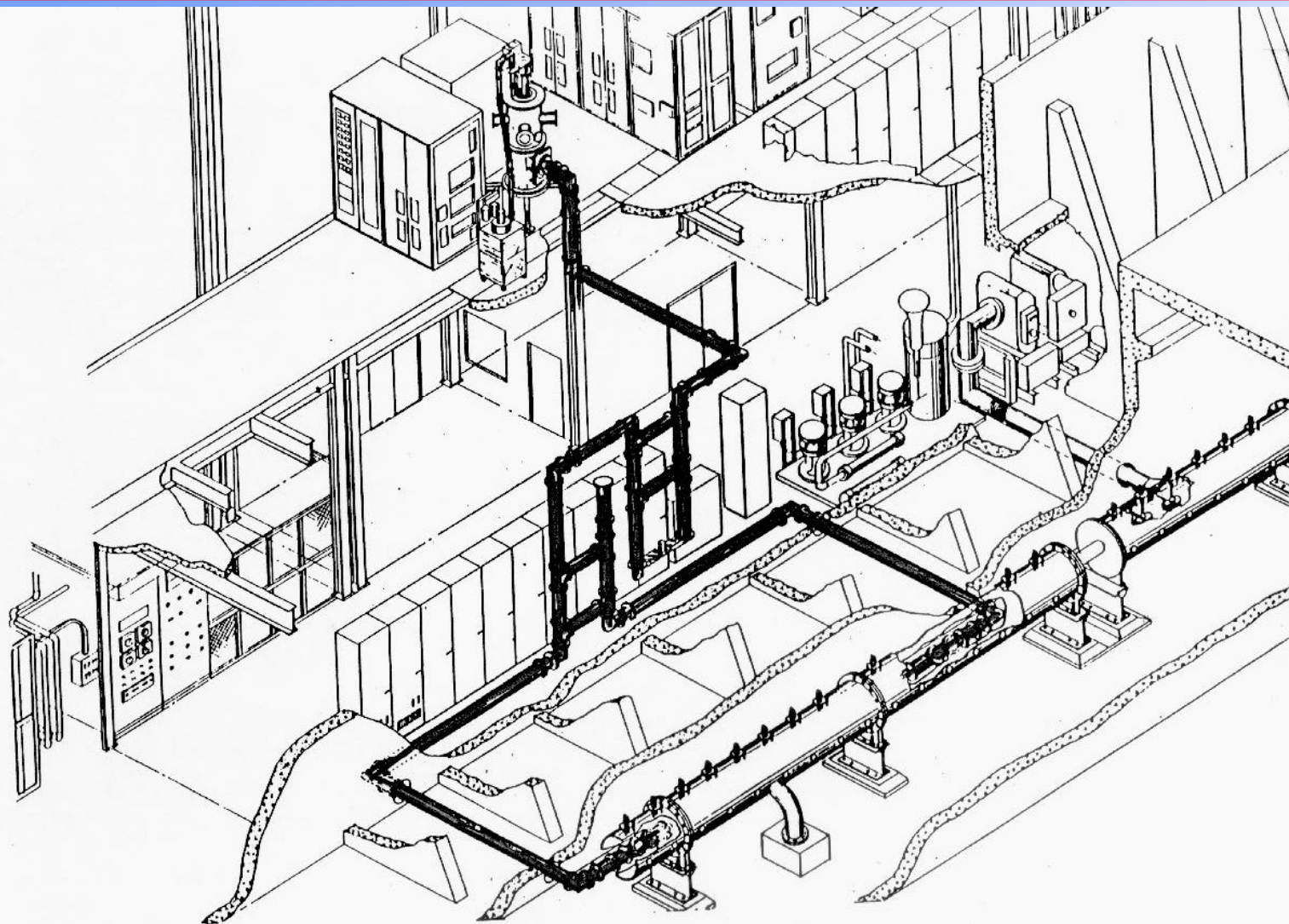
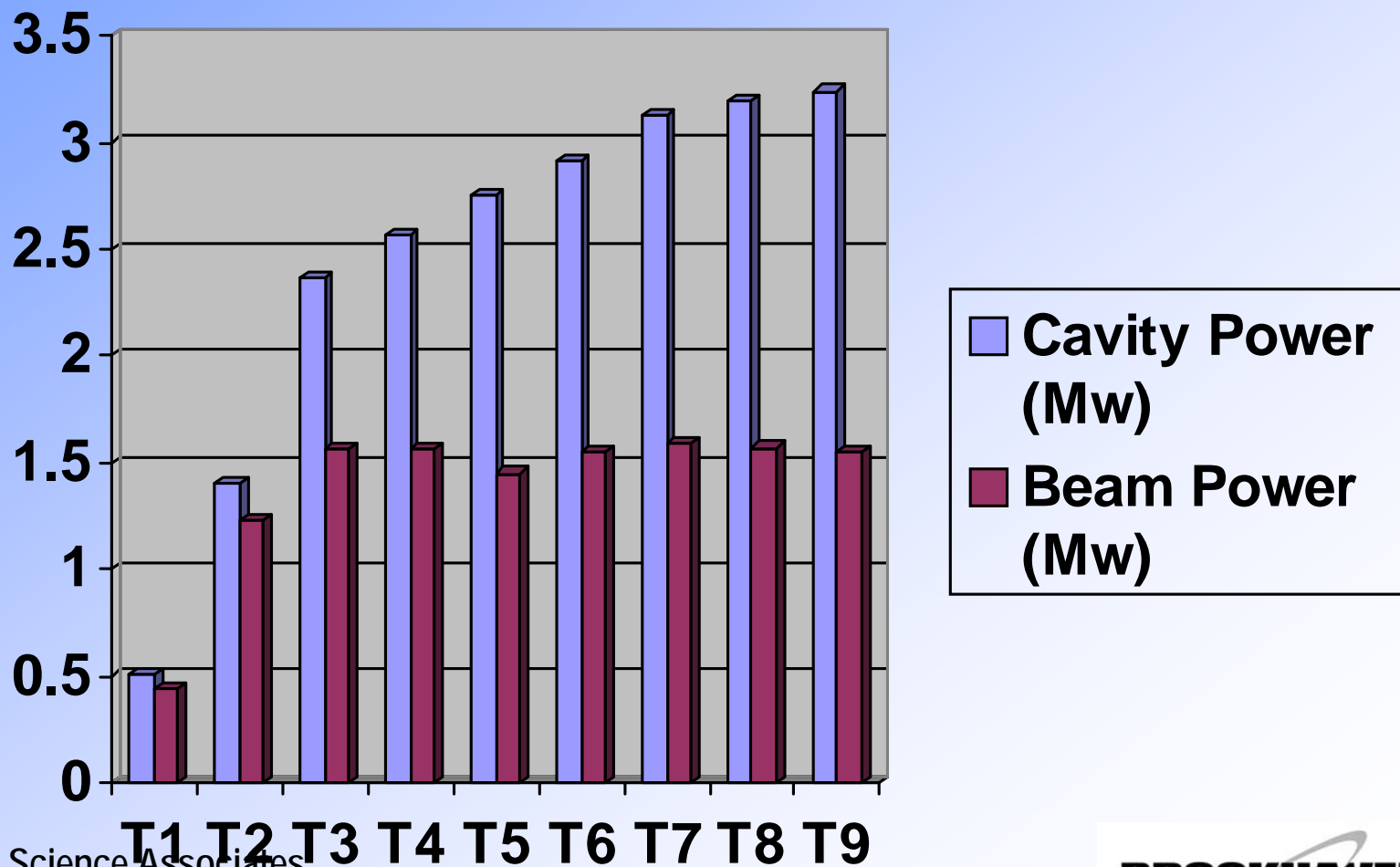
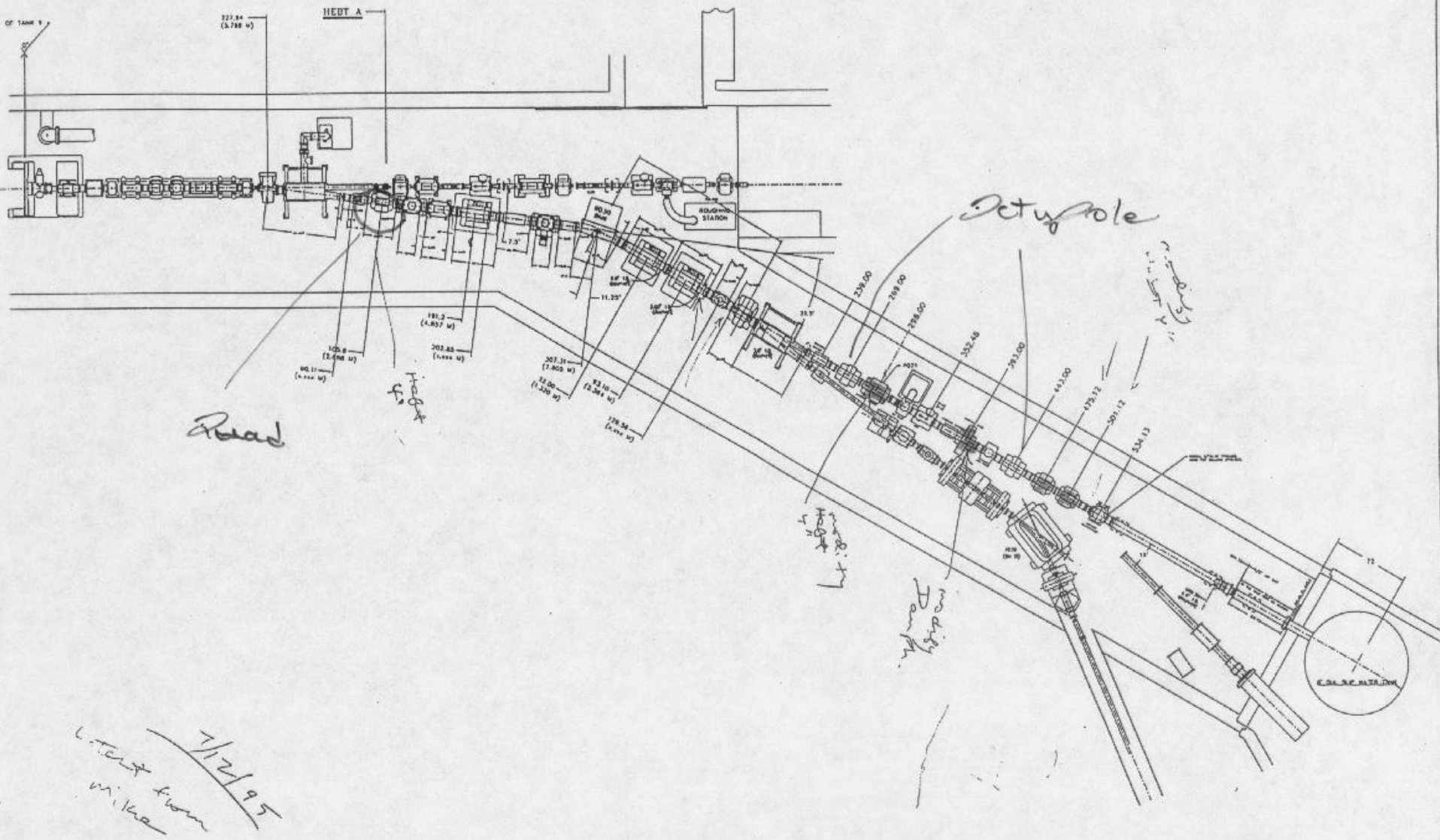


FIGURE III.3.b.2 RF transmission-line layout.

Linac Power



Layout of BLIP Beam Line



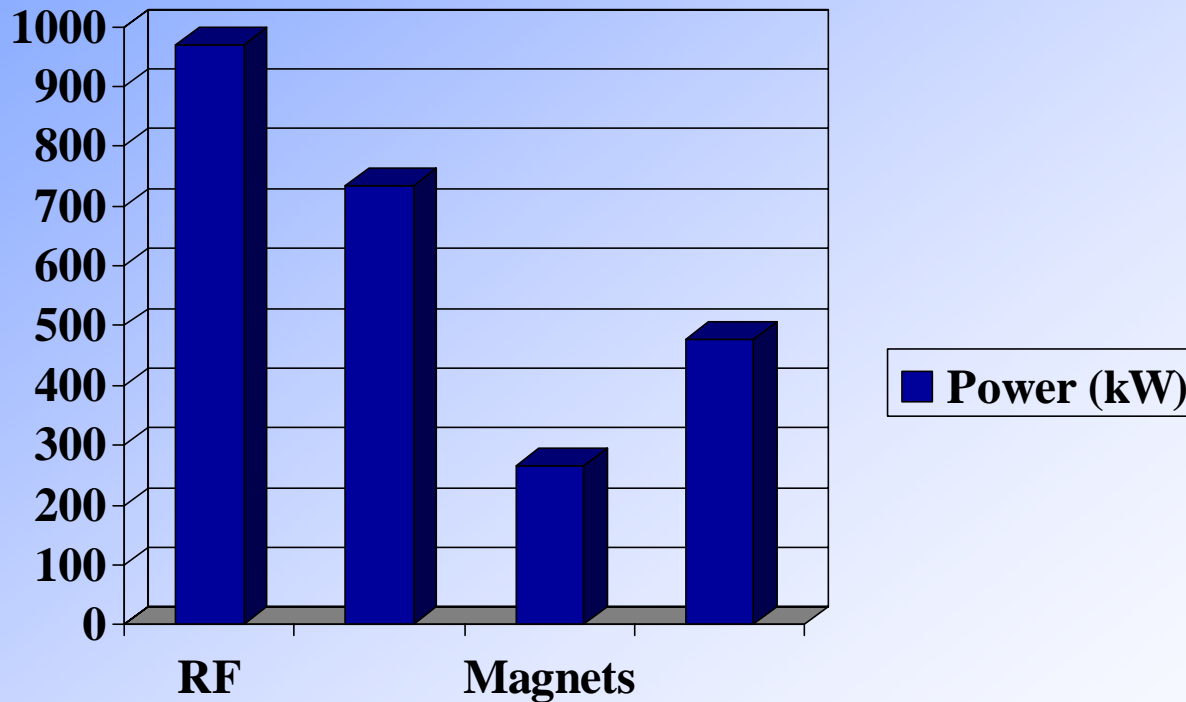
Diagnostics in the Linac

- Transformers
 - where located
 - how fast response
- Emittance measurements
- Harps, SEMS
- Fast pickups
 - not used much
- Stripline position monitors

Diagnostics in the Linac

Device	LEBT	MEBT	Tanks	HEBT	LTB	BLIP
Trans.	1	3	9	3	3	3
Pol. Trans.			1		2	
FC	1	1				
Fast FC		1				
Emitance		2				
Sems			8	3	3	1
Harps				1	3	2
BLIP			6	3	4	

Power to Run Linac -2.5 MW (7.5 Hz, 140 μ A)



Linac Power

Vin/Brian/Spinner measurements, 7/15/96, as linac turned off.

(note: Vin reported 50 kW type fluctuations in the measurements, as va

	kW	Differential	
Linac full on (7.5 Hz, 140 uA)	2438		
BLIP transport off	2206	232	
RF and quad pulsing off	1943	263	(Quads < 20 kW)
RF HV PS off	1925	18	
LEBT bunchers off	1920	5	
HEBT off	1934	-14	
7835 filaments to 6000 A	1705	229	
4616's off	1651	54	
7835 plate modulators off	1544	107	
7835 filament off (from 6000 A)	1226	318	
LEBT sol/chop/extr off	1223	3	
LEBT pulsed quads/RFQ off	1212	11	
Tank cooling water off	1072	140	
Transport water off	1045	27	
RF cooling water off	794	251	
Source	793	1	
BLIP cooling water	788	5	
Chillers off	478	310	

Remaining = building, lights, vacuum, etc.

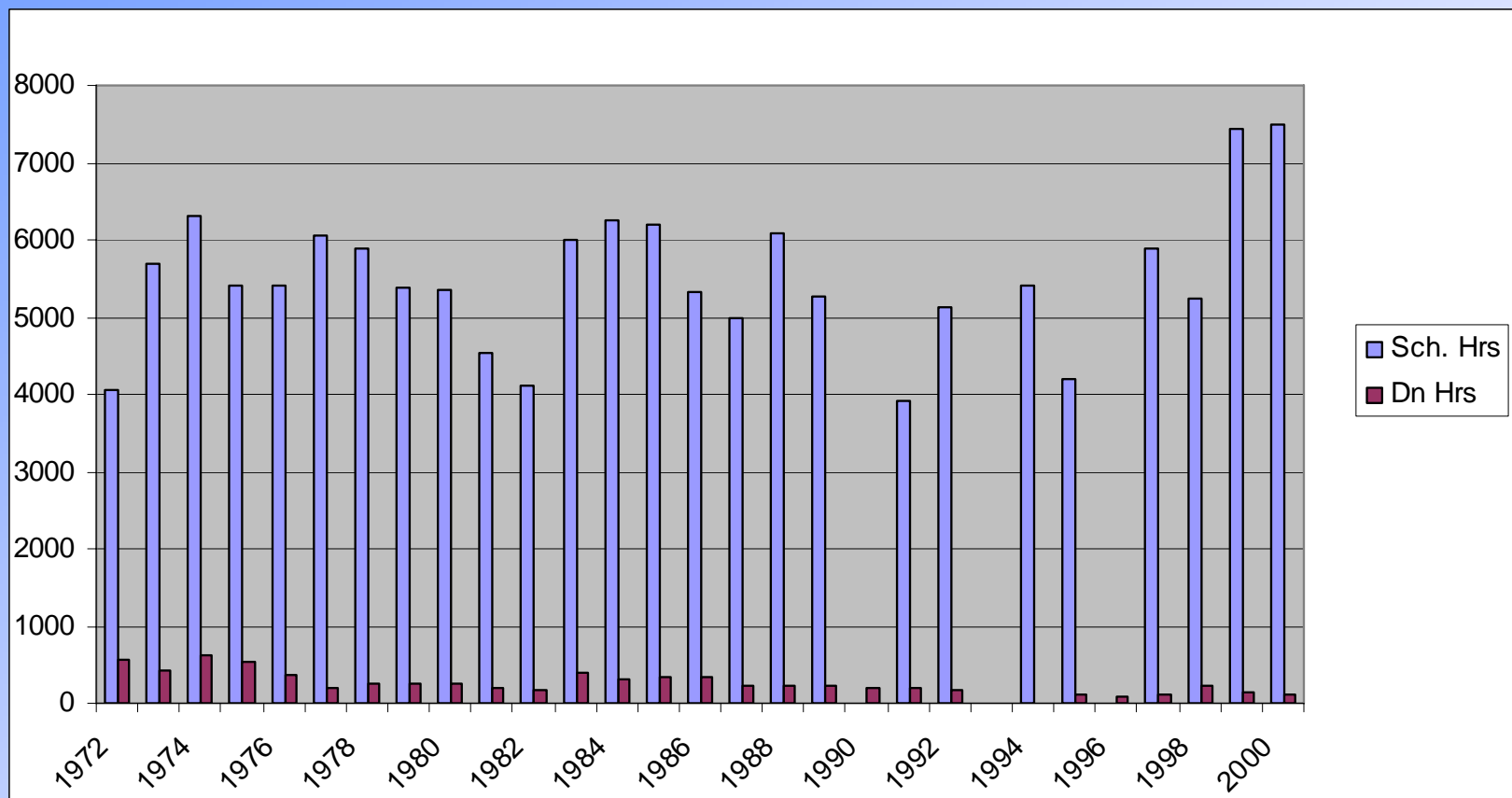
RF systems:

RF pulsing off	243
RF HV PS off	18
7835 filaments to 6000 A	229
4616's off	54
7835 plate modulators off	107
7835 filament off (from 6000 A)	318

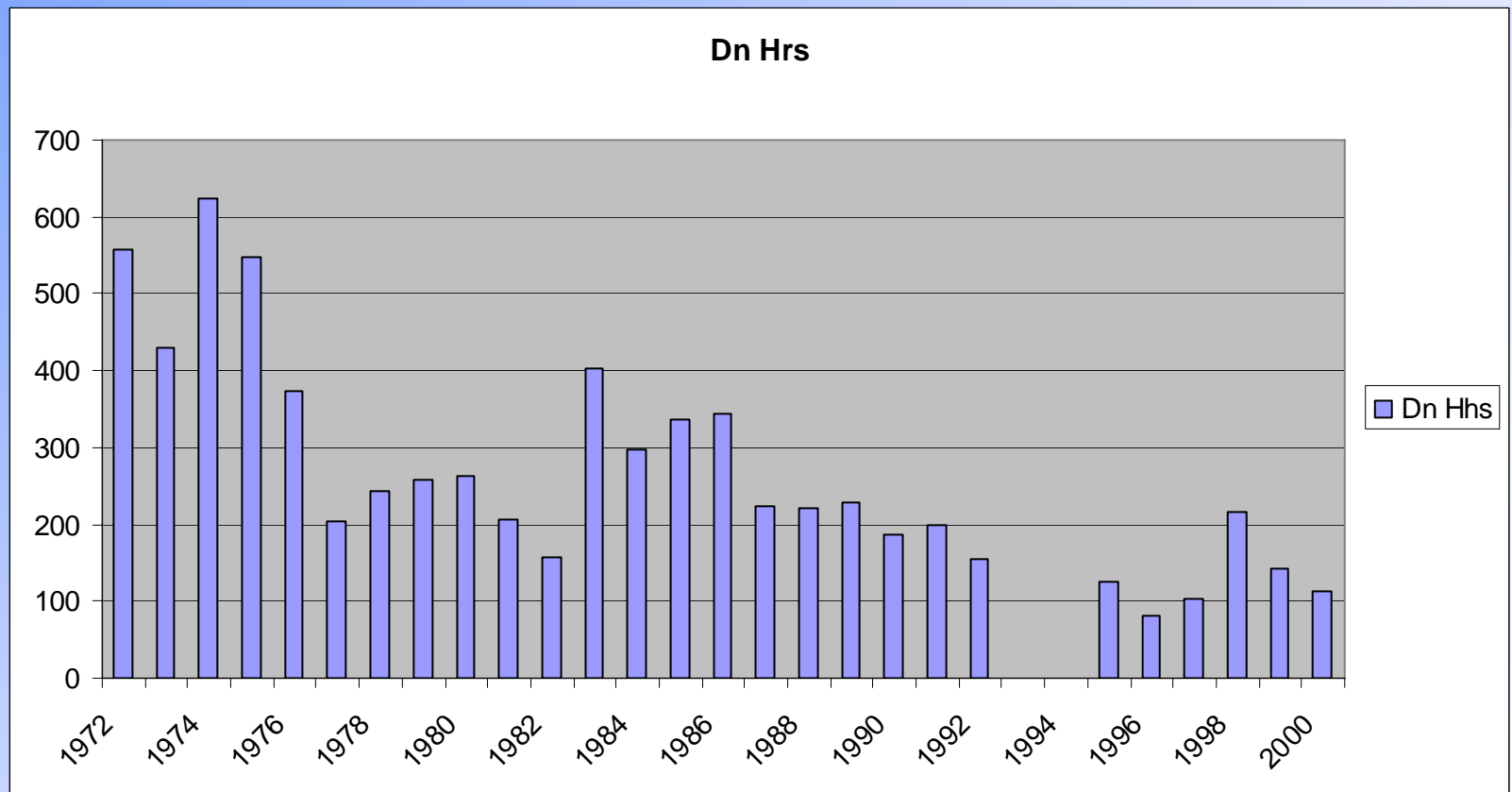
TOTAL RF 969

Pwr/sys 107.66667

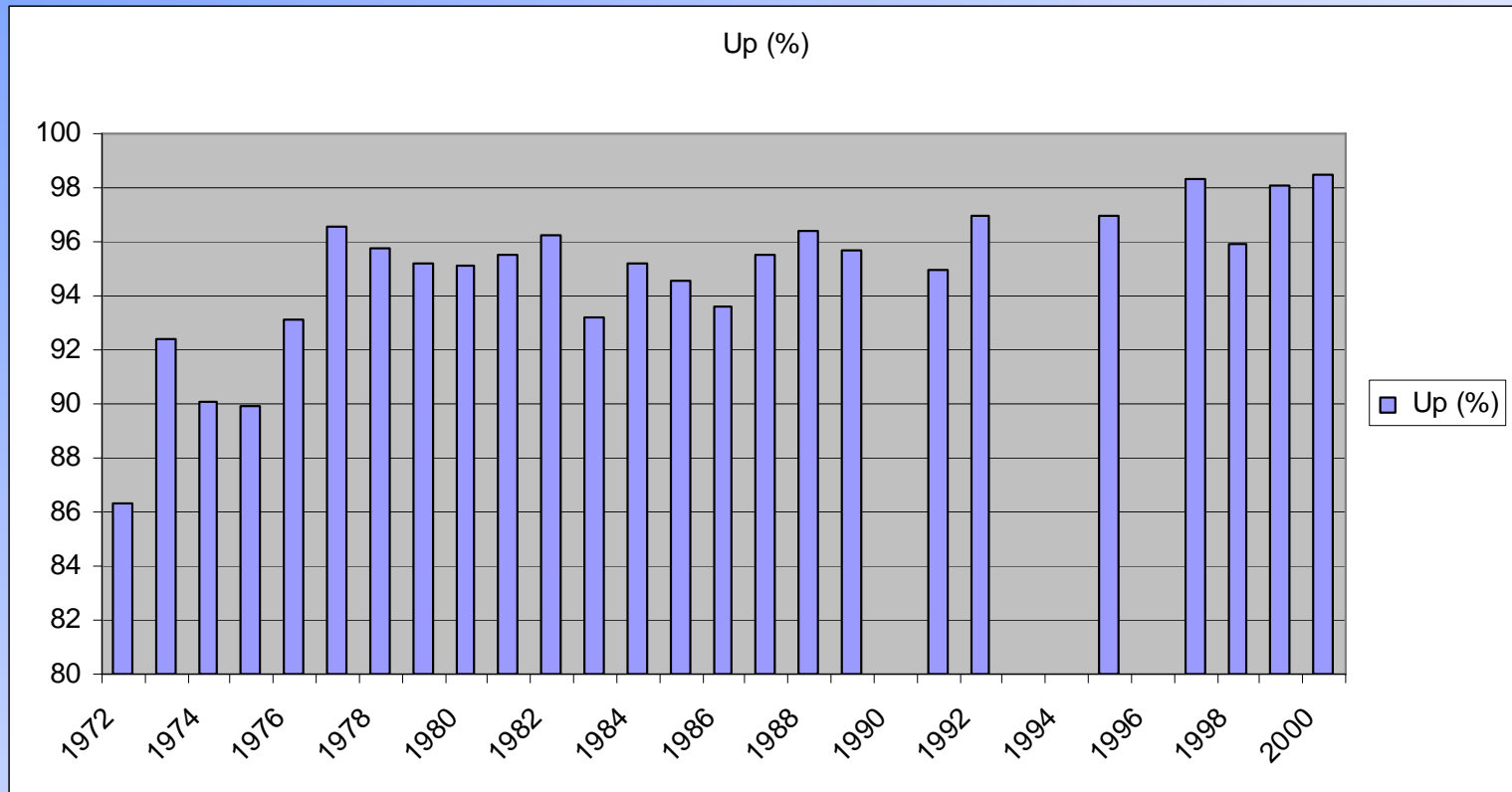
Linac Operation



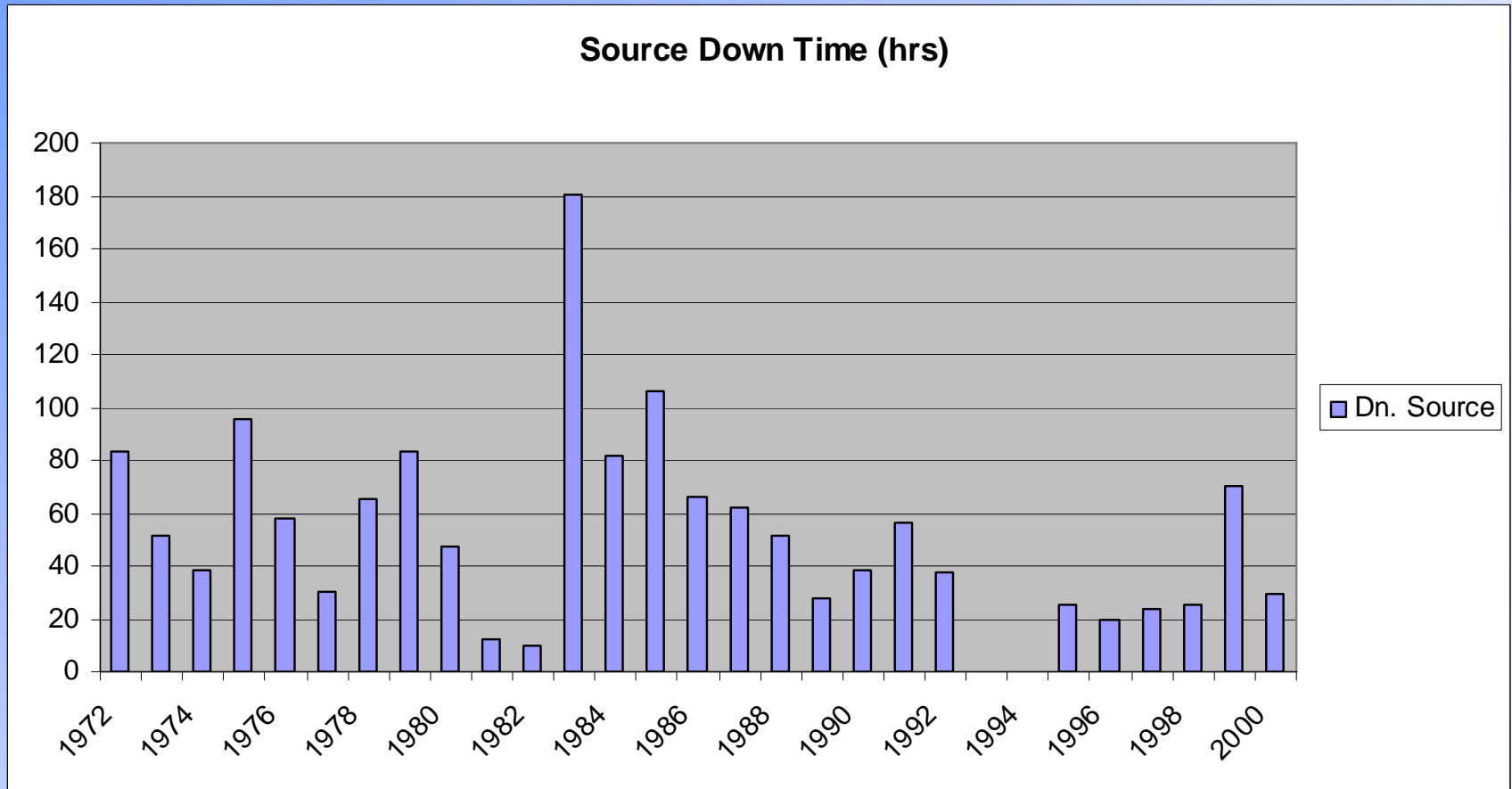
Linac Operations (cont.)



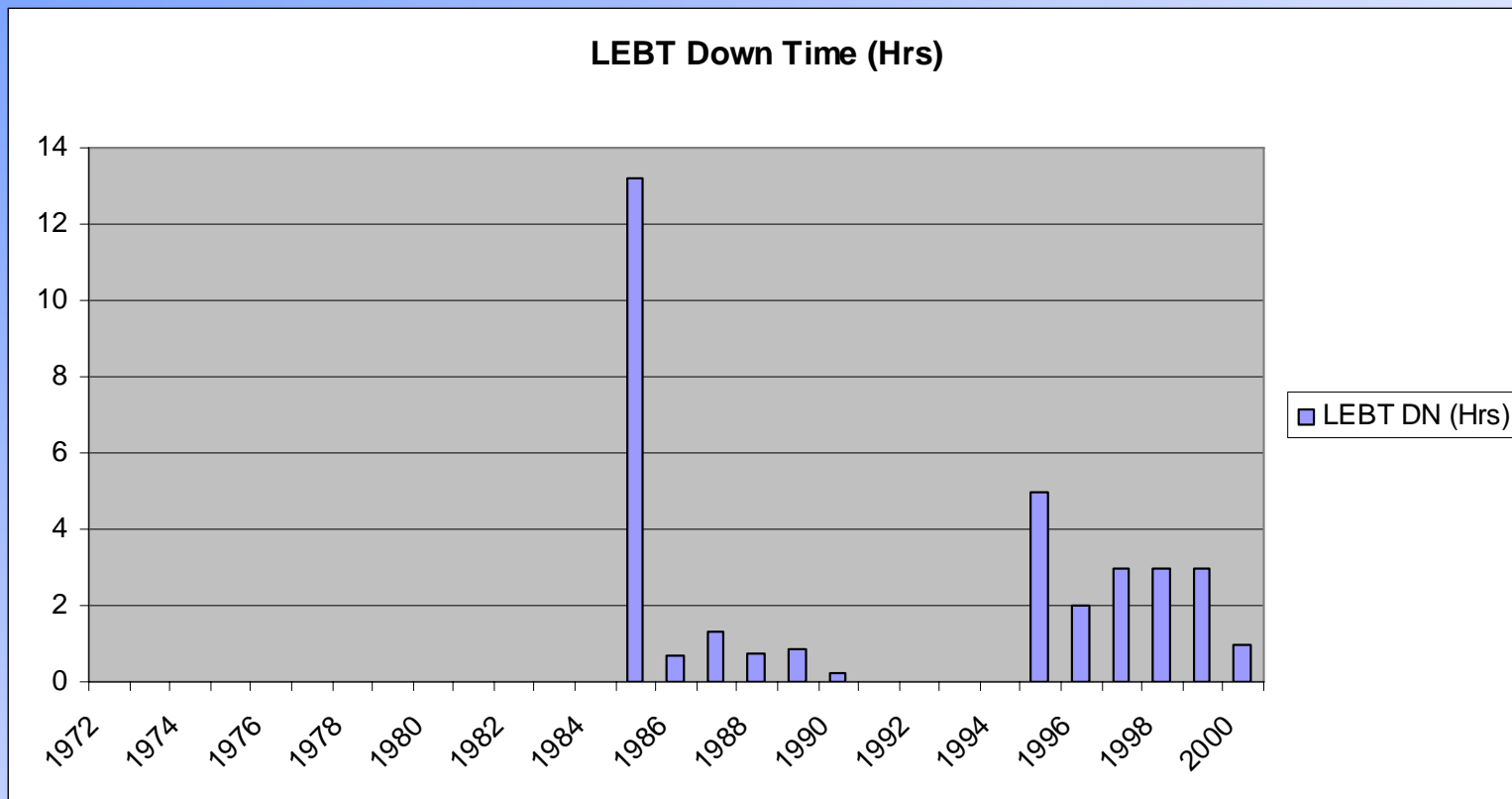
Linac Operations (cont.)



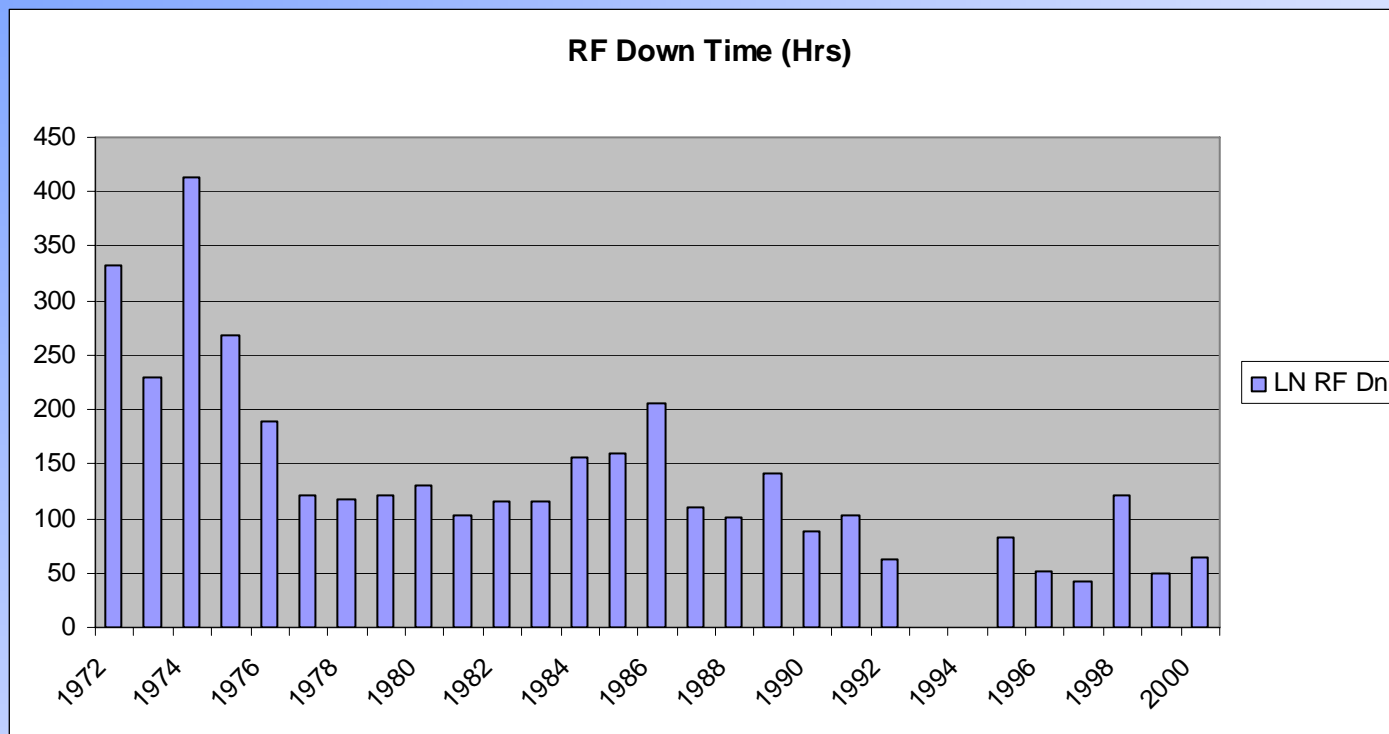
Linac Operation (cont.)



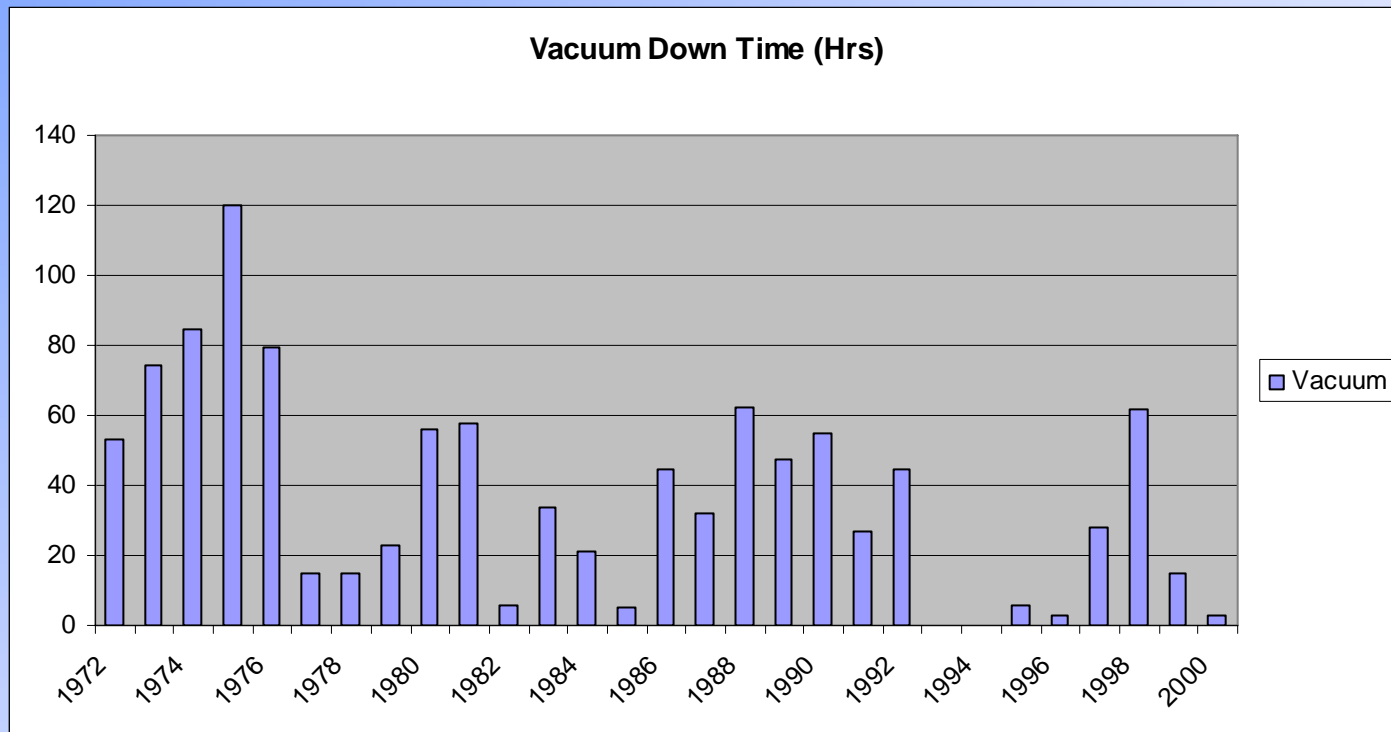
Linac Operation (cont.)



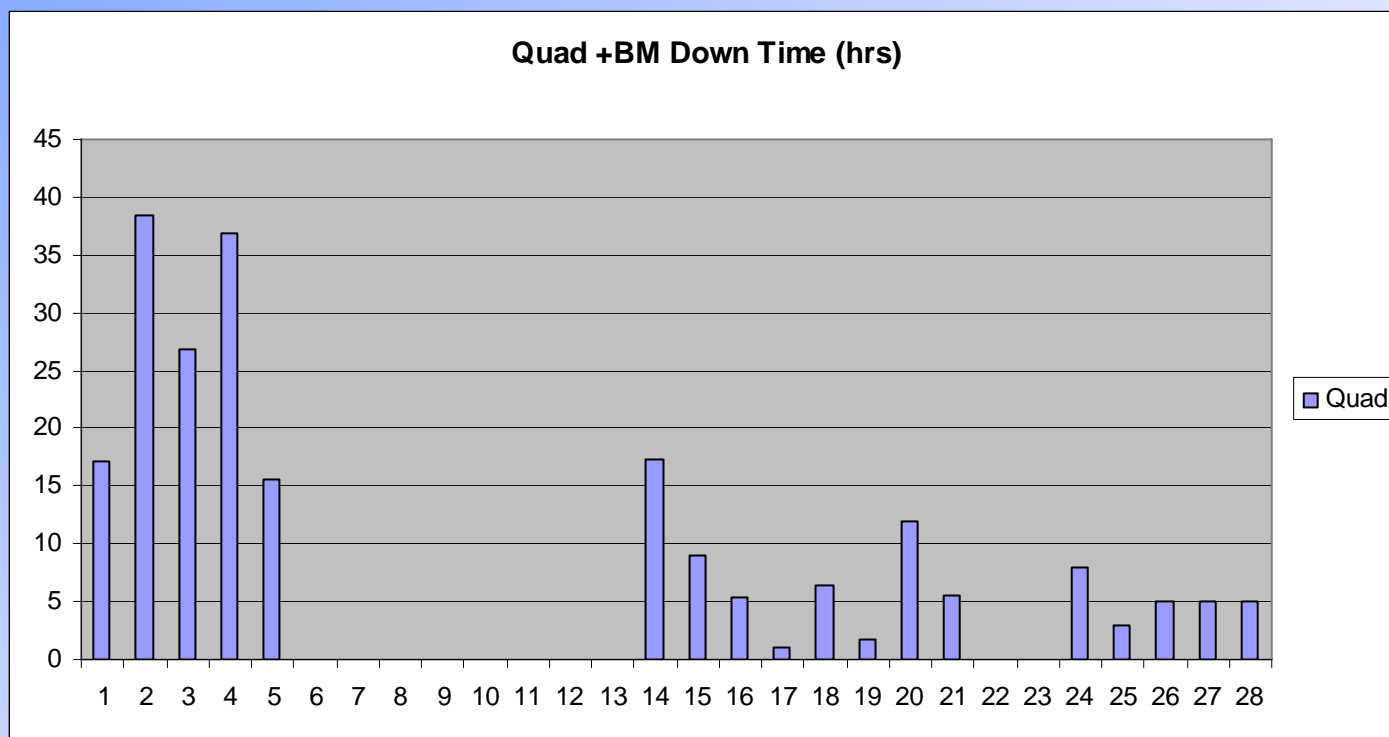
Linac Operation (cont.)



Linac Operation (cont.)



Linac Operation (cont.)



Linac Operation (cont.)

